

Why District Energy is a Key Element in the Danish Energy Strategy

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Scope:

- Role of CHP in Danish Power sector
- Role of district energy in Danish heating and in Danish CHP
- Overview of current and future Copenhagen District heating system
- Role of district heating in Danish energy and environmental policy

Historical background

The development of the Danish CHP concept started sometime between the two world wars. In the bigger cities, municipal supply companies were responsible for the supply of electricity, town gas and domestic tap water, and power plants were therefore often owned by the municipalities.

The combined production of power and heat started with a supply of steam to hospitals in the neighbourhood of the power plants, where the steam was used for process purposes. Later on the steam was also used for room heating and extended to domestic areas. After the Second World War water-based CHP production was established. The background for this development was the energy savings obtainable through the combined production of heat and power.

Parallel to the development with CHP in the bigger cities district heating schemes were also established in smaller communities during the 1960's. The base here was the co-operative idea, which for centuries has been a natural part of the Danish society. The price difference between heavy fuel oil used at DH-plants and light gas-oil used for individual heating formed the basis for the development. Utilisation of surplus heat from waste incineration plants in the district heating systems was also started during the 1960's.

Up to 1972 when the first energy crises hit Europe, all initiatives regarding the development of CHP and district heating were based on local initiatives in the municipalities or in private co-operative companies.

When the energy crises came in 1972 the energy situation in Denmark turned out to be very critical. The figure below shows the distribution of gross consumption of primary energy in 1972. Oil took up 92%, coal 6% while 2% were based on the incineration of waste.

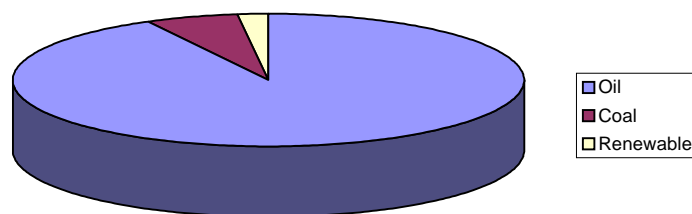


Figure 1. Distribution of gross energy consumption in Denmark in 1972

At that time oil was imported as well as coal, and therefore Denmark was in a situation where energy was lacking, and at the same time the costs related to the consumption of energy were doubled or more over a very short period.

Therefore, it was a mandatory for the Danish government - in order to maintain the affluent society that had been build up within the last decade - to work out an effective Danish Energy Strategy.

The Danish Energy Strategy

Since the energy crises in 1972 the Danish Energy Strategy can be divided into three periods, each with a different primary goal.

- The late 1970's with focus on the security of supply (self-sufficiency)
- The 1980's with focus on the national economic optimisation
- The 1990's with focus on the environmental protection

In the first period, where security of supply was high on the priority list, it was important to reduce the consumption of energy in general and also to distribute this consumption on several primary energy sources in order to reduce the consumption of oil. Of course domestic energy sources were therefore preferred to imported energy.

Due to the energy savings CHP is a very good solution in that connection. The combined production thus means that heat can be produced with efficiencies of 300% to 400% compared with individual heat production with efficiencies of 85% to 90%. At the same time the centralised production offers a better possibility for the conversion of primary energy.

District heating is necessary for the utilisation of CHP production, but the centralised production and the connected distribution systems have also big advantages both regarding the utilisation of different heating options and regarding the flexibility in the choice of primary energy sources.

For many years an extension of CHP based district heating has therefore been supported by the Danish government through grants and subsidies to new mainlines. Back in 1976 it was also decided that all new power plants to be erected in Denmark should be based on CHP.

Due to the efficient use of energy in a CHP concept, CHP and district heating were also promoted during the national economic period in the 1980's. By law local governments were thus forced to carry out heat mapping and energy planning projects, while the power sector and the district heating companies were forced to implement the projects. Big centralised CHP schemes were established in all densely populated areas in Denmark during this period.

One should be aware of the fact that all energy companies were operated during that period as monopolies under a non-profit law regulated by the government. By means of energy taxes national economic projects were made macro-economic feasible for the end users.

During the ongoing environmental phase CHP and district heating are still having a high priority in the Danish Energy Strategy. Small-scale CHP schemes based on gas engines and gas turbines have been implemented in large numbers in the sparsely populated areas all over the country.

Power sector

For decades the Danish power production has been based on conventional steam turbine technology. Nuclear power is not found in Denmark, and hydropower has never had any significance. Within the last ten years wind power has come into focus and is supported by the government. The implementation of CHP schemes has therefore been technical unproblematic in Denmark, and so far there have been no conflict with the general optimisation of power production.

For decades the Danish power system has been connected to the neighbouring systems in Sweden, Norway and Germany. These system are all characterised by a big share of hydropower or nuclear power, and therefore Denmark typically imports power during the summer period, where there is a surplus of hydropower in Norway and Sweden, and exports power during the winter period. The import/export relations are therefore changing according to the weather conditions. Figure 2 shows the production and net import of power in selected years.

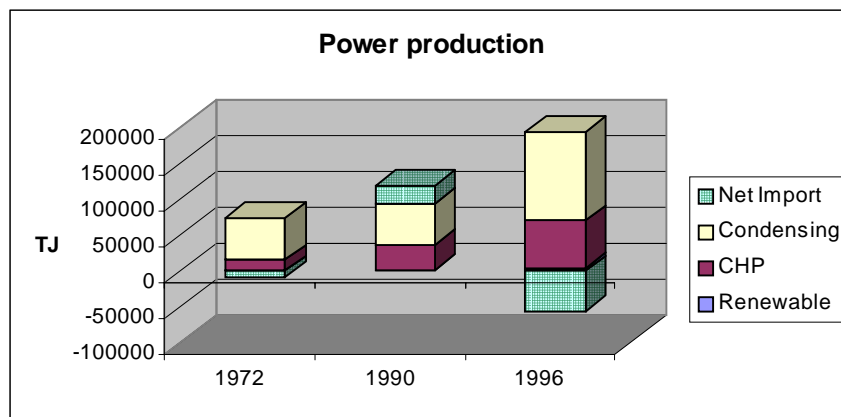


Figure 2

The share of CHP based production has grown larger year by year, and today approximate 50% of the national power demand is covered by CHP based power production. Wind power is to day covering 8% of the national power demand, and according to plans this share is to be extended even further in the future by the implementation of big offshore windmill parks.

Problems are therefore to be foreseen in the future, where the amount of wind-based power and the heat bound power on CHP plants exceed the national power demand in certain periods. Exchange of power on the international market is therefore a prerequisite for the Danish Energy Strategy.

The CHP plants can be divided into the big centralised plants and the smaller decentralised plants, where the centralised plants consist of extraction turbines and the decentralised plants of back-pressure turbines, gas turbines or gas engines, depending on the size of the plant.

District Heating sector

District heating has a central role in the heating sector in Denmark. District Heating thus covers 50% of the national heat demand. There are more than 450 district heating companies in Denmark giving an average of one plant for each 11,000 inhabitants or for each 100 km². Figure 3 shows the development of district heating in Denmark.

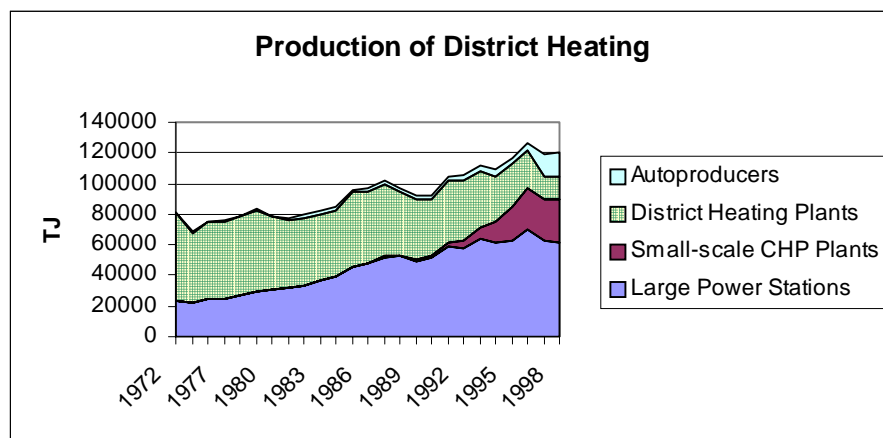


Figure 3

Today, almost 80% of the production of district heating in Denmark are based on CHP production while in 1972 the CHP share was merely 25%.

The success of district heating is primary related to the utilisation of the effective CHP production, but the big flexibility in district heating itself is also of big importance for the Danish Energy Strategy. Heat is one of the lowest ranging types of energy, and therefore, district heating can be utilised for distribution of production from all kinds of production units, including waste and surplus heat from different kind of industrial processes. The centralised production with few production plants makes conversion of primary fuel possibly contrary individual production.

Figure 4 shows the consumption of primary energy for production of district heating in selected years. The heat efficiency on the CHP plants is set to 260%.

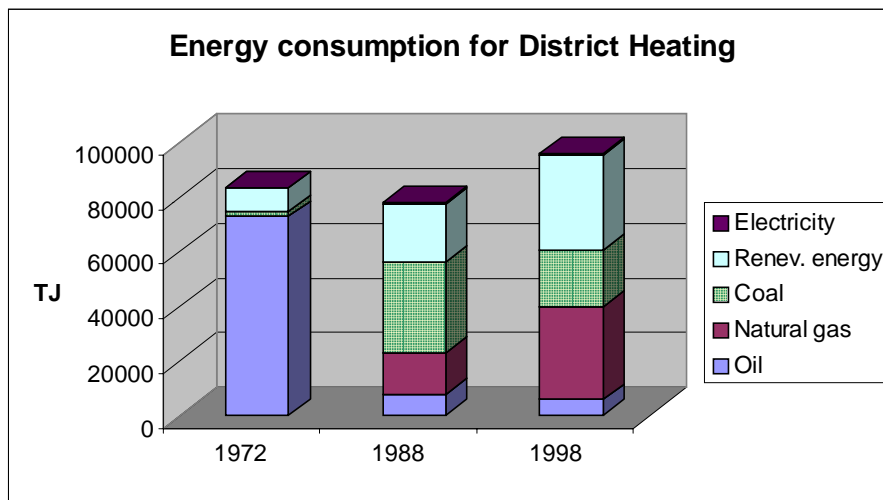


Figure 4

In 1972 the dominating fuel was oil, but due to the flexibility of the district heating systems it was possible to convert to other fuels within a period of 10 to 15 years. Due to the international energy prices coal was chosen as the primary fuel in the power sector. After 1988 where the environment has been at the centre of attention, the focus has now moved to natural gas and renewable energy. Today, incineration of waste is the primary renewable energy source, but bio-fuels are on the agenda for the years to come.

Due to the climate conditions and the building philosophy have district cooling so far not been introduced in Denmark, but demonstration projects are however under construction.

Danish energy and environmental policy

The conversion and the energy savings achieved till now would have been impossible if district heating and CHP had not been implemented in the extent as it has actually happened. Following achievements can be highlighted:

- Energy consumption per square meter for heating is reduced to 50% of the demand in 1972.
- Share of oil in gross energy consumption is reduced from 92% in 1972 to today's 45%.

- Share of fossil fuels used for district heating is reduced from 90% to today's 63%.
- The energy intensity per GDP is reduced to 60% of the 1972 value.
- The import/export adjusted CO₂ emission is reduced to 92% of the 1988 value.

The Copenhagen district heating system

Four of the large numbers of district heating systems, that are presently operating in Denmark, are so-called inter-municipal or regional transmission systems. The Metropolitan Copenhagen Heating Transmission Company (CTR) is the largest of these systems. The foundation of the CTR transmission company dates back to February 1984 and was managed by a group of five municipalities, all located in the Greater Copenhagen area. The system now includes 54 km of 25 bar double pipeline with pipe diameters ranging from 250 to 800 mm. Added to which there are 26 heat exchanger stations and three booster pump stations, approximately 13 peak load stations and four different heat-generating installations (CHP-plants, waste incineration plants and purification plants) with an installed capacity of 1,600 MW.

The total gross heat requirement is estimated to 20,000 TJ or 5.6 TWh/year when fully extended on the distribution side in the year 2002, corresponding to 275,000 dwelling units being connected. Estimated consumer connection varies from 90% to 98% in the individual partner municipalities.

The CTR-system is also connected to a similar system, the VEKS-system serving the area west of the Copenhagen area. This co-ordination of the two transmission systems has a number of obvious advantages as regard the production, including a mutually guaranteed supply between the two companies in event of break-downs or other force majeure situations at the heating plants. It is also possible to utilise the load distribution between the two co-ordinated systems, which ensures the most economic operation of both the heat and power systems.

Altogether the two systems attend to 3/4 million people's energy need - or 18% of the entire Danish population - thus forming what is often referred to as one of the largest district heating systems in the world.

As to the environmental consequences of the establishment of the CTR project, it has been estimated that the emissions of CO₂ will be reduced by approximately 50% of present levels (equal to 750,000 tons), and the emissions of SO₂ by some 35%, when the network has been fully extended in the year 2002. At the same time the computed oil substitution effect will amount to some 450,000 tons of oil per year, and the equivalent net energy savings to some 290,000 tons of oil per year. In economic terms, this result will save the Danes approximately 500 million DKK (equal to 92 mil US\$) per year.

Today the system is more or less fully extended technically. In the future old coal fired power units will be replaced by modern natural gas fired units and units using bio-fuels.

Conversion units:

- 1 m ~ 3.28 ft ~ 39.4 in
- 1 km ~ 0.622 mile
- 1 km² ~ 0.387 sq mile
- 1 TJ ~ 3.6 GWh ~ 948 10⁶ Btu
- 1 MW ~ 3.41 10⁶ Btu/h
- 1 bar ~ 14.5 psi